THE DAMAGE TO STRUCTURES CAUSED BY THE SECOND MIYAKOJIMA TYPHOON

AUTHOR(S):

ISHIZAKI, Hatsuo; KATSURA, Junji; MUROTA, Tatsuo

THE DAMAGE TO STRUCTURES CAUSED BY THE SECOND MIYAKOJIMA TYPHOON

by Hatsuo ISHIZAKI, Junji KATSURA and Tatsuo MUROTA

(Manuscript received May 8, 1968)

Abstract

From 5th to 6th September 1966, the Second Miyakojima Typhoon (6618, Cora) struck the Sakijima Islands, Okinawa, and moved northwest along the south coast of Miyakojima Island as slowly as 10 km/h bringing a severe wind force never experienced before. The damage to structures caused by this typhoon was severest in Miyakojima and in the northeast area of Ishigakijima. In Miyakojima the rate of damaged houses was around 50%, although most of them were wooden structures.

1. Introduction

A severe wind storm caused by the Second Miyakojima Typhoon struck the Sakijima Islands, Okinawa, from 5th to 6th September 1966, and devastated most towns in Miyakojima and the northeast area of Ishigakijima. The damage was severest in Miyakojima, where the rate of completely destroyed houses was as high as 17.6%. The authors investigated the damage caused by this typhoon in Miyakojima and Ishigakijima Islands in October 1966. This paper reports on the damage to structures according to the investigation.

2. General wind pattern of the typhoon

The general wind pattern of the Second Miyakojima Typhoon is described in detail in another paper. [1] We shall now make a brief comment on it.

From 5th to 6th September 1966, this intense typhoon passed northwestward over the Sakijima Islands. The eye wall of the typhoon moved as slowly as 10 km/h along the south coast of miyakojima, where a severe storm with a wind speed of more than 40 m/s lasted for about 13 hours. The maximum wind speed of 60.8 m/s (NE) (06h31m, Sept. 5), the maximum peak gust of 85.3 m/s (NE) (07h31m, Sept. 5) and the minimum atmospheric pressure of 928.9 mb were observed at the Miyako Weather Station, Miyakojima Island.

3. Types of buildings in Okinawa

Several typhoons with severe wind storms attack the Okinawa area every year. The expected maximum wind speed in Miyakojima for example is 67 m/s every 100 years, 46 m/s every 10 years and 30 m/s every 2 years. [2] In these circumstances buildings in Okinawa are usually designed so as to resist the force of a wind of more than 68 m/s at 10 m above ground. [3]

Most of the buildings in Okinawa are wooden hip-roofed ones with tile roofings, which are divided into two types; clay tile roofings and cement tile roofings. (Photo. 1, Fig. 1)

4. Definition of terms and notations

In order to describe the extent of the damage to buildings, we shall use several terms here following the definitions below:-

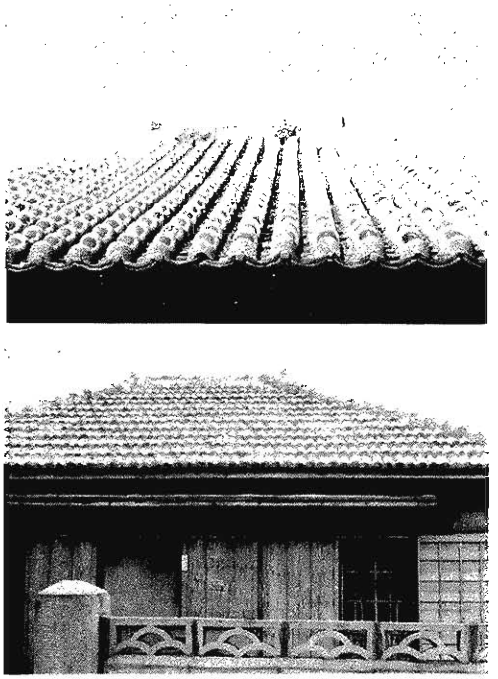


Photo. 1 Two types of roofings of wooden buildings in Okinawa :
(a) clay-tile roofing, (b) cement-tile roofing.

completely destroyed: damaged by wind to the extent that the expense of repairs is more than 70% of the total construction cost

badly damaged: damaged by wind to the extent that the expense of repairs is more than 30% of the total construction cost

rate of completely destroyed houses: ratio of the number of completely destroyed houses to the total number

rate of badly damaged houses : ratio of the number of badly damaged houses to the total number

rate of damaged houses : sum of the two rates defined above

Notations

N_t = total number of houses

N_c = number of completely destroyed houses

N_b = number of badly damaged houses

R_c = rate of completely destroyed houses = N_c/N_t

R_d = rate of damaged houses = $(N_c+N_b)/N_t$

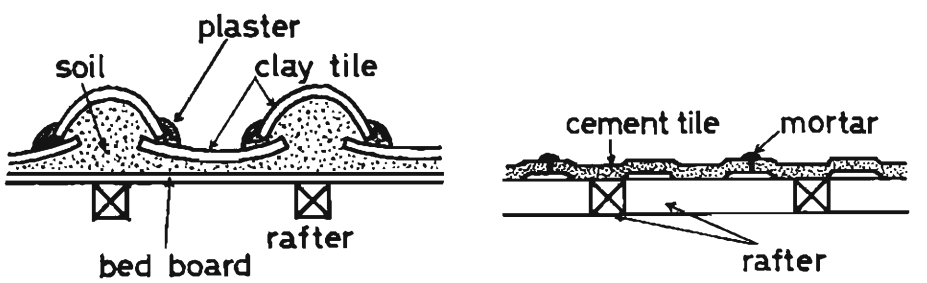


Fig. 1 Two types of roof sections of wooden buildings in Okinawa.
(a) clay-tile roofing, (b) cement-tile roofing.

5. Brief view of the damage

The Second Miyakojima Typhoon brought about severe damage to the Sakijima Isls, where most of the damage was caused by the force of the wind, not by the flood.

The damaged buildings were mainly wooden buildings, but steel structures were also damaged. Reinforced concrete buildings were only partly damaged.

Table 1 shows the number of damaged houses in Miyakojima and Ishigakijima by administrative districts, which is illustrated in Fig. 2 in the case of Miyakojima.

Table 1 Damage to houses caused by Typhoon 6618 by administrative districts.

DISTRICT	N_t	N_c	N_b	R_c(%)	R_b(%)
MIYAKOJIMA ISLANDS					
HIRARA CITY	6657	703	1826	10.6	38.1
GUSUKUBE-CHO	2602	650	797	25.0	55.6
SHIMOJI-CHO	980	302	354	30.8	66.9
UENO-MURA	821	288	452	35.1	90.1
TOTAL	11060	1943	3429	17.6	31.1
ISHIGAKIJIMA ISLANDS					
ISHIGAKI CITY	8163	71	139	0.9	2.6

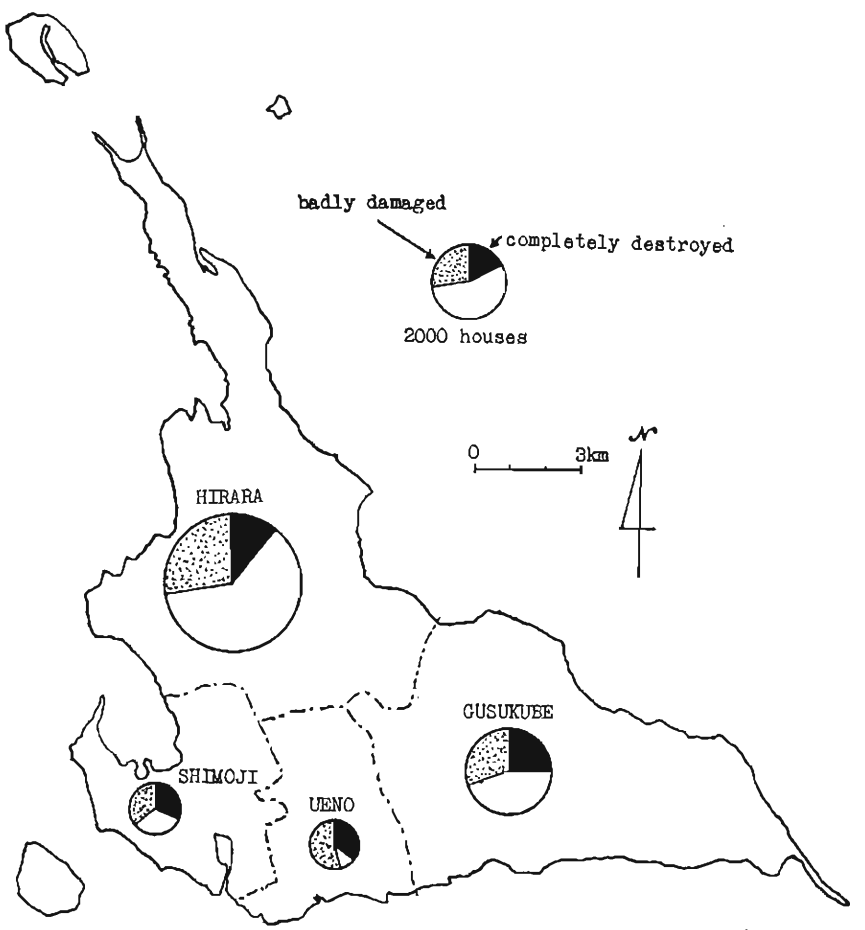


Fig. 2 Damage to houses by administrative districts in Miyakojima.

Table 2 Damage to houses in communities on Miyakojima.

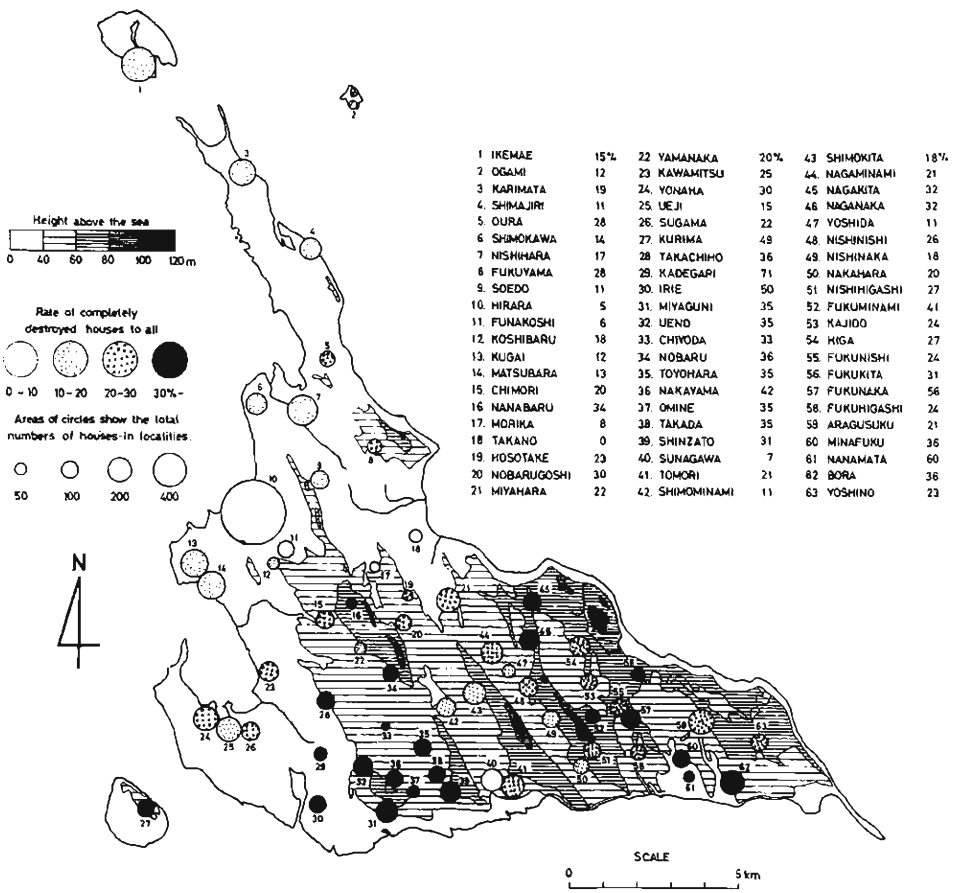
COMMUNITY	N_t	N_c	N_b	R_c %	R_d %	COMMUNITY	N_t	N_c	N_b	R_c %	R_d %
HIRARA CITY											
CITY ZONE	3447	175	715	5.1	20.1	MIYAHARA	239	53	60	22.2	47.3
KOSHIBARU	57	10	14	17.6	42.2	TAKANO	54	0	3	0	5.6
FUNAKOSHI	88	5	33	5.7	43.2	SOEDO	108	12	14	11.1	24.1
KUGAI	261	32	95	12.2	48.6	SHIMOKAWA	130	18	62	13.8	61.4
MATSUBARA	332	42	85	12.6	38.2	NISHIHARA	363	60	159	16.6	60.5
NANABARU	44	15	18	34.2	75.2	FUKUYAMA	46	13	30	28.4	93.7
SHINTOYO	11	—	—	—	—	OURA	105	29	25	27.6	51.4
CHIMORI	108	22	65	20.4	80.6	SHIMAJIRI	140	15	45	10.7	42.9
YAMANAKA	108	21	36	19.5	52.9	KARIMATA	279	53	145	19.0	71.1
NOBARUGOSHI	114	34	37	29.9	62.4	OGAMI	25	3	18	12.0	84.0
MORIKA	36	3	2	8.4	14.0	IKEMAE	510	76	143	14.9	43.0
HOSOTAKE	52	12	22	23.1	65.6	TOTAL	6657	703	1826	10.6	27.5
GUSUKUBE-CHO											
BORA	177	64	39	36.2	58.2	HIKA	138	37	69	26.8	76.8
YOSHINO	107	25	21	23.4	43.0	NAGAKITA	79	25	11	31.6	45.5
NANAMATA	35	21	4	60.0	71.4	NAGANAKA	105	34	18	32.4	49.5
MINAFUKU	89	32	40	35.9	80.8	NAGAMINAMI	115	24	25	20.8	42.5
ARAGUSUKU	213	44	69	20.6	53.0	YOSHIDA	56	6	12	10.7	32.1
FUKUHIGASHI	95	23	42	24.3	68.7	NISHINISHI	106	28	28	26.4	52.8
FUKUNAKA	85	48	27	56.4	88.1	NISHINAKA	98	18	56	18.4	75.5
FUKUNISHI	95	23	26	24.3	51.6	SHIMOKITA	182	33	40	18.1	40.1
FUKUMINAMI	79	32	35	40.5	84.8	SHIMOMINAMI	101	11	13	10.9	31.7
FUKUKITA	55	17	25	30.9	76.3	SUNAGAWA	181	12	22	6.6	24.3
NISHIHIGASHI	92	25	38	27.2	68.5	TOMORI	180	37	57	20.5	52.1
NAKAHARA	61	12	37	19.7	80.3						
KAJIDO	78	19	25	24.4	56.4	TOTAL	2602	650	797	25.0	55.6
SHIMOJI-CHO											
KURIMA	94	46	26	49.0	76.7	KATEKARI	41	29	8	70.6	90.1
YONAHA	243	73	83	30.0	64.2	TAKACHIHO	95	34	48	35.8	86.3
UEJI	185	27	77	14.6	56.2	KAWAMITSU	122	30	44	24.6	60.7
SUGAMA	130	28	58	21.5	66.1						
IRIE	70	35	10	50.0	64.3	TOTAL	980	302	354	30.8	66.9
UENO-MURA											
UENO	103	36	57	34.9	90.2	TAKATA	85	30	47	35.3	90.6
NAKAYAMA	84	35	46	41.7	96.4	TOYOHARA	108	38	59	35.2	89.8
MIYAGUNI	139	49	76	35.2	89.8	NOBARU	92	33	51	35.8	91.2
OMINE	40	14	22	35.0	90.0	CHIYODA	27	9	15	33.3	88.8
SHINZATO	143	44	79	30.7	85.9	TOTAL	821	288	452	35.1	90.1

The damage in Miyakojima was quite extensive, but in Ishigakijima on the other hand the damage was confined to the northeast area and was minor in other regions.

6. Distribution of damage in Miyakojima Island

Miyakojima is a flat Island about 180 km² in area, the highest point of which is 108 m above the sea. Trees and forests grow sparsely and most parts of the island are covered by sugar cane fields, so Miyakojima is unduly exposed to the force of the wind. (Photo. 3) Table 2 and Fig. 3 show the rate of damaged houses in communities on Miyakojima. In some communities 60% of the houses were completely destroyed and 90% were damaged. As averages the

Photo. 2 Typical Miyakojima landscape.



1	IKEMAE	15%	22	YAMANAKA	20%	43	SHIMOKITA	18%
2	OGAMI	12	23	KAWAMITSU	25	44	NAGAMINAMI	21
3	KARIMATA	19	24	YONAHA	30	45	NAGAKITA	32
4	SHIMAJIRI	11	25	UEJI	15	46	NAGANAKA	32
5	OURA	28	26	SUGAMA	22	47	YOSHIDA	11
6	SHIMOKAWA	14	27	KURIMA	49	48	NISHINISHI	26
7	NISHIHARA	17	28	TAKACHIHO	36	49	NISHINAKA	18
8	FUKUYAMA	28	29	KADEGAPI	71	50	NAKAHARA	20
9	SOEDO	11	30	IRIE	50	51	NISHIHIGASHI	27
10	HIRARA	5	31	MIYAGUNI	35	52	FUKUMINAMI	41
11	FUNAKOSHI	6	32	UENO	35	53	KAJIDO	24
12	KOSHIBARU	18	33	CHIYODA	33	54	HIGA	27
13	KUGAI	12	34	NOBARU	36	55	FUKUNISHI	24
14	MATSUBARA	13	35	TOYOHARA	35	56	FUKUKITA	31
15	CHIMORI	20	36	NAKAYAMA	42	57	FUKUNAKA	56
16	NANABARU	34	37	OMINE	35	58	FUKUHIGASHI	24
17	MORIKA	8	38	TAKADA	35	59	ARAGUSUKU	21
18	TAKANO	0	39	SHINZATO	31	60	MINAFUKU	36
19	HOSOTAKE	23	40	SUNAGAWA	7	61	NANAMATA	60
20	NOBARUGOSHI	30	41	TOMORI	21	62	BORA	36
21	MIYAHARA	22	42	SHIMOMINAMI	11	63	YOSHINO	23

Fig. 3 Rate of completely destroyed houses in communities on Miyakojima.

rates of completely destroyed and damaged houses were 17.6% and 48.7% respectively. Such a high rate of damage seems to be because of the open nature of the island and the lack of trees to break the force of the wind.

7. Distribution of damage in Ishigakijima Island

Table 3 and Fig. 4 show the damage to houses in communities on Ishigakijima. The damage is confined to the communites on the northeast peninsula and is minor in other regions. So the average rates of completely destroyed and damaged houses are very small compared with Miyakojima, being 0.9% and 2.6% respectively. This is considered to be mainly due to the relatively long distance from the center of the typhoon and also to the wind-shelter effect of the topography. In fact the maximum wind speed of 27.3 m/s and the maximum peak gust of 44.9 m/s observed at the south coast of Ishigakijima are about half those in Miyakojima.

Table 3 Damage to houses in communities on Ishigakijima.

COMMUNITY	N_t	N_c	N_b	R_c %	R_d %	COMMUNITY	N_t	N_c	N_b	R_c %	R_d %
TONOSHIRO	1962	0	6	0	0.3	MIYARA	285	0	5	0	1.8
OKAWA	922	0	0	0	0	SHIRAHO	390	0	1	0	0.3
ISHIGAKI	920	0	4	0	0.4	ISOBE	43	0	0	0	0
SHINKAWA	1427	0	1	0	0.1	KAWAHARA	88	0	0	0	0
NAGURA	104	0	0	0	0	MIWA	34	0	26	0	76.5
TAKEDA	48	0	2	0	4.2	KAINAN	21	0	0	0	0
MOTONAGURA	19	0	5	0	26.3	OMOTO	23	0	0	0	0
SAKIEDA	73	0	1	0	1.4	OSATO	40	0	1	0	2.5
KABIRA	127	0	13	0	10.2	HOSHINO	63	2	0	3.2	3.2
OTAKE	17	1	7	5.9	47.1	INODA	104	0	2	0	1.9
NAKASUJI	9	0	0	0	0	ONO	19	0	0	0	0
YOSHIHARA	54	0	3	0	5.6	IBARUMA	73	17	22	22.3	52.8
YONEHARA	31	0	6	0	19.4	NOSOKO	210	0	25	0	11.9
TOMINO	14	0	3	0	21.4	AKASHI	67	17	10	25.4	40.3
OTA	21	0	0	0	0	KUURA	51	0	1	0	1.9
ITONA	24	0	7	0	29.1	YOSHINO	25	0	4	0	16.0
MAESATO	70	0	1	0	1.4	HIRAKUBO	37	1	5	2.9	16.2
HIRATOKU	220	1	1	0.5	1.0	HIRANO	68	30	19	44.1	72.1
OHAMA	460	0	0	0	0	TOTAL	8163	71	139	0.9	2.6

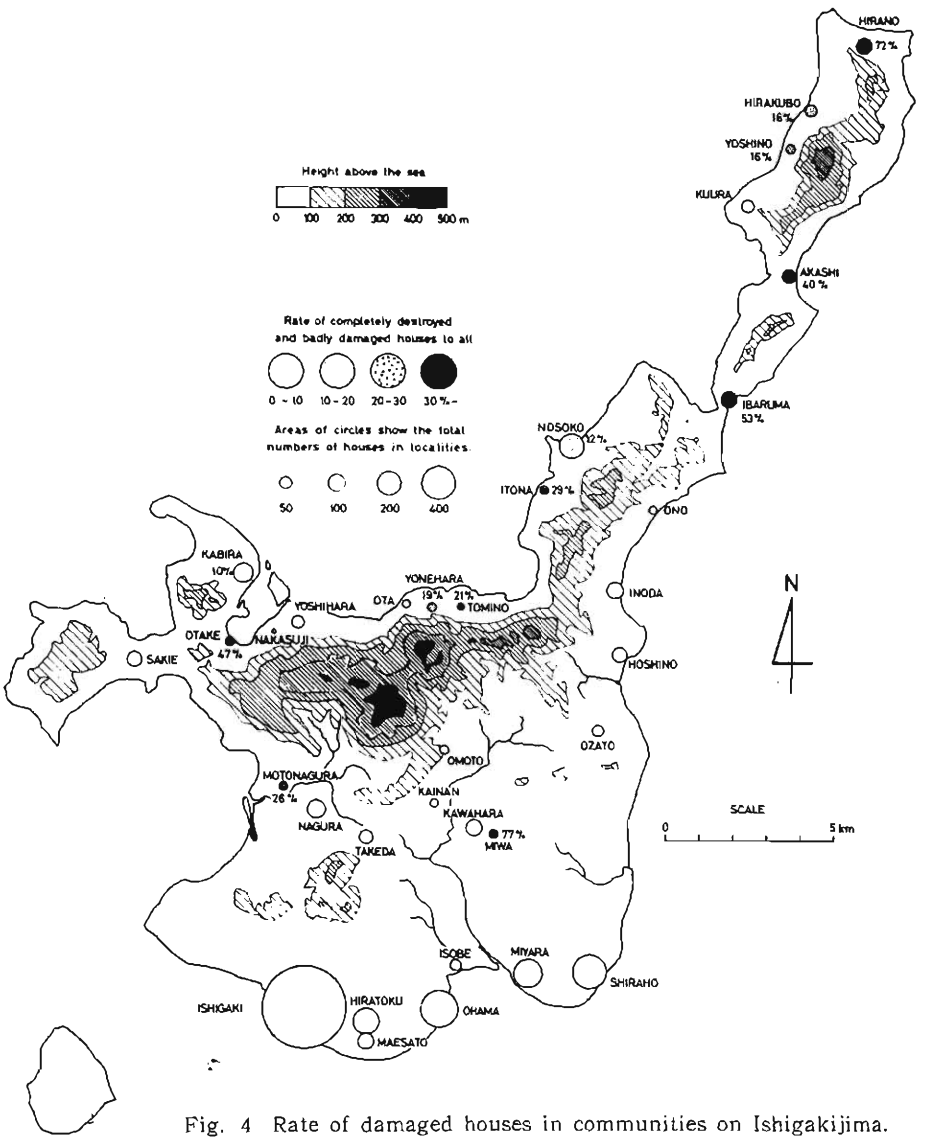


Fig. 4 Rate of damaged houses in communities on Ishigakijima.

8. Distribution of damage in the city

Table 4 shows the damage to houses in 21 communities in the city zone of Hirara City, Miyakojima, excluding the rural districts. In the city zone the rate of completely destroyed houses of 5.1% is 1/3 of the average value of 16.7 % in Miyakojima.

Table 4 is illustrated in Fig. 5, indicating that the damage in the windward communities was severer than in the downwind ones.

Table 4 Damage to houses in the city zone of Hirara City.

COMMUNITY	N_c	N_a	N_b	R_c %	R_d %	COMMUNITY	N_t	N_a	N_b	R_a %	R_d %
MINAMINISHIZATO	346	13	22	3.8	10.2	DEGUHI	142	4	12	2.8	11.3
KAMIYA	166	5	10	3.0	9.0	AZUMA	158	16	45	10.1	38.6
OMITAWARA	299	2	11	0.7	4.4	SAKAE	131	12	18	9.2	23.0
MAEPIYA	149	4	5	2.7	6.1	NAKAYA	206	19	44	9.2	30.5
UEZUNO	128	4	17	3.1	16.4	ASAHI	111	6	42	5.4	43.2
OHARA	155	2	85	1.3	56.2	TAKAARA	115	8	32	7.0	34.9
HARIMIZU	182	3	28	1.6	17.0	HIGASHIKAWANE	136	11	17	8.1	20.6
KITANISHIZATO	191	2	13	1.0	7.8	NAKAHOYA	139	18	64	13.0	59.1
NEMA	158	3	6	1.9	5.7	HOSATO	145	16	80	11.0	66.2
SHIMOYA	198	8	36	4.0	22.2	NIKAWATORI	101	14	85	13.9	98.1
HADATE	91	5	43	5.5	52.9	TOTAL	3447	175	715	5.1	20.8

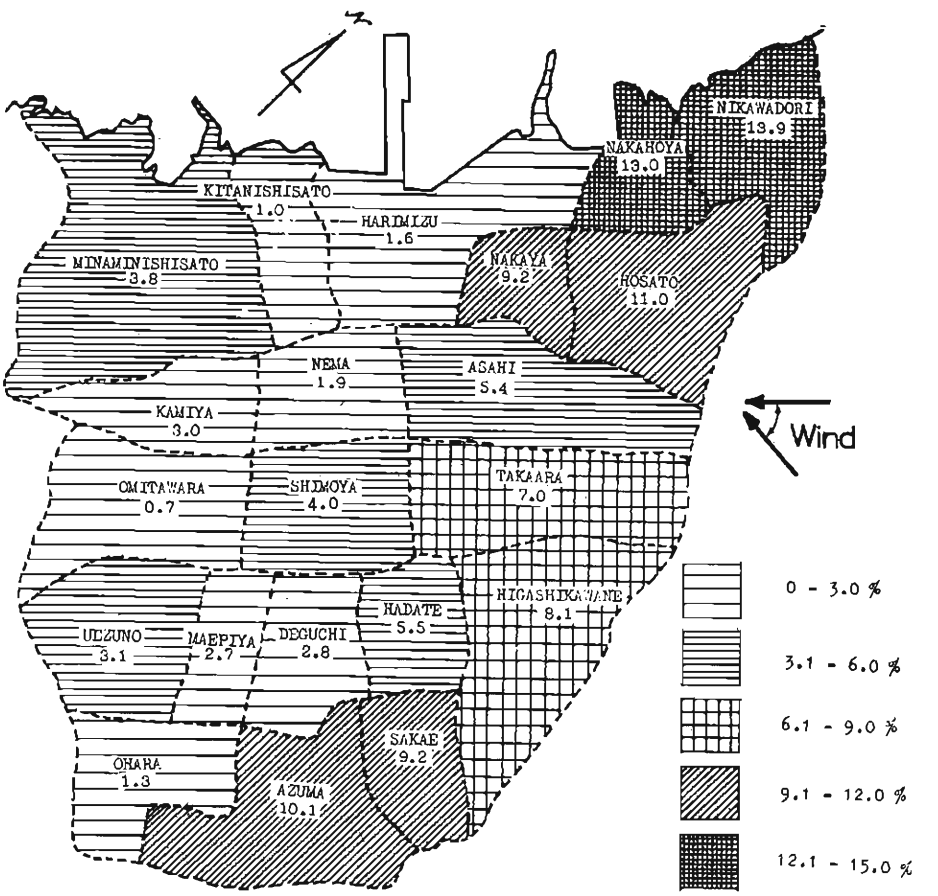


Fig. 5 Zoning map of completely destroyed houses in Hirara City.

9. Structural types of damage

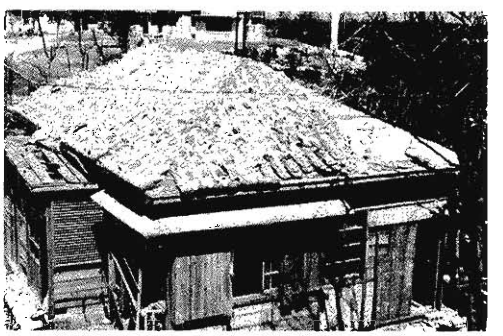
Reinforced concrete buildings. Reinforced concrete buildings of schools, offices, dwellings were only partly damaged; mostly broken doors and windows. (Photo. 3)

Wooden buildings. The damage to wooden buildings appeared to differ in feature according to the type of roofings:-

Photo. 3 Damage to reinforced concrete buildings; a broken door.

(a)

(b)



(c)

(d)

(e)

Photo. 4 Damage to wooden buildings with clay-tile roofings ;
(a) wreckage of openings, (b), (c) removal of tiles from ridges and corners, (d) removal of tiles from the eave, (e) total destruction of a school building. (by courtesy of the Miyako Bureauof Local Administration =(a), (b), Hirara City Hall= (d), and The Okinawa Times=(e)).

(1) damage to wooden buildings with clay- or cement-tile roofings with bed boards were as follows: (Photo. 4)

i) broken doors and windows

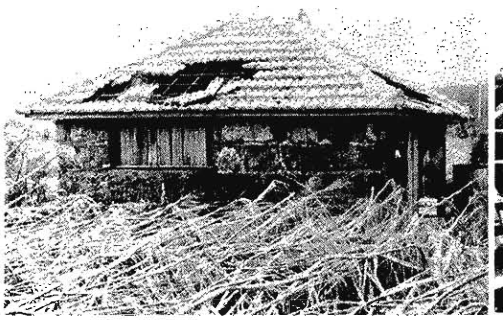
ii) removal of roof tiles from eaves, ridges, verges or corners

iii) total destruction

(2) damage to wooden buildings with cement-tile roofing without bed boards were as follows: (Photo. 5)

(a)

(b)



(c)

(e)

(d)

Pohto. 5 Damage to wooden building with cement-tile roofing :

(a) lifting of tiles from a leeward roof, (b) removal of tiles from eave, (c) (d) removal of tiles from leeward roofs, (e) total destruction of a house. (by courtesy of Hirara City Hall=(b), the Miyako Bureau of Local Administration = (c), the U. S. Civil Administration of the Ryukyus = (d) and The Okinawa Times = (e)).

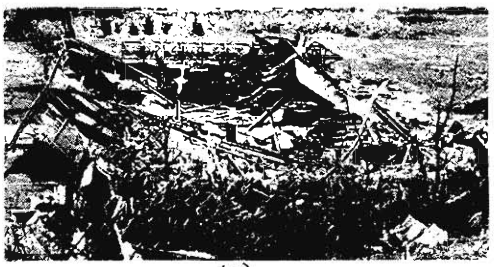
i) broken doors and windows
ii) lifting of tiles from leeward roofs
iii) removal of tiles from leeward roofs, eaves or verges
iv) total destruction

The lifting and removal of tiles are closely related with damage to openings in the walls.

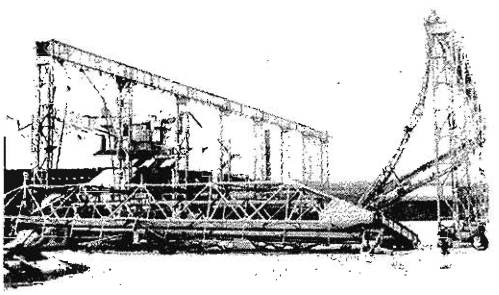
Steel frames. Damage to steel framed buildings occurred in sugar factories and a warehouse of the U.S. Army. The sugar factories were galvanized iron structures and many galvanized iron plates were removed from the walls or roofs. The warehouse was a gable-roofed steel frame and callapsed completely downwind. (Photo. 6)

Reinforced masonry buildings with wooden roofs. Masonry buildings were not so much in number as wooden buildings but most of them were seriously damaged. The damage was mostly the bodily removal of wooden roofs, because of the weak connection between roofs and walls. (Photo. 7)

Towers and similar structueres. Table 5 shows the damage to towers and similar structures. The damage was generally not so serious, which indicate that proper structural design keeps them safe against the force of winds of 60 m/s.



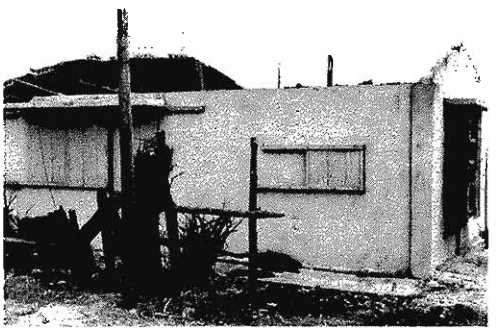
(a)



(b)

Photo. 6 Damage to steel framed structures: (a) collapse of a gable-roofed warehouse, (b) collapse of a track crane at a sugar factory (by courtesy of the U. S. Civil Administration of the Ryukyus= (a) and the Miyako Bureau of Local Administration =(b)).

(a)



(b)

Photo. 7 Damage to masonry buildings with wooden roofs : (a), (b) bodily removal of roofs (by courtesy of The Ryukyu Shimpo=(a)).

Table 5 Damage to towers and similar structures in Miyakojima.

	TYPE	SITE	DAMAGE
antenna	steel truss, G. L. +35m	in flat, sugar-cane field, Hirara City	separation of paint by wind (Photo. 8)
	guyed pile, reinforced concrete, G. L. +12m	top of a hill, Hirara City	slip-off of a guy cable, cracks in the windward side of the pile (Photo. 9)
chimney	reinforced concrete and steel, G. L. +20m	in a sugar factory, Shimoji	no damage (Photo. 10)
flag mast	steel pipe, 90ϕ, G. L. +11m	top of a hill, Hirara City	displacement of the top about 30cm leeward; estimated wind speed is 60.5m/sec (Photo. 11)

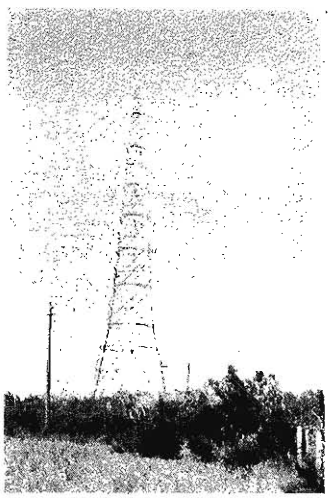


Photo. 8 Damage to a steel truss antenna : separation of paint by wind.

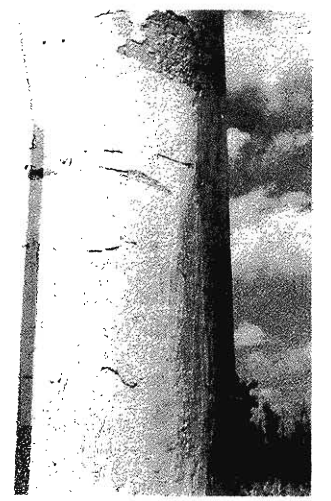


Photo. 9 Damage to a reinforced concrete antenna : cracks in the windward side.

10. Conclusions

From the investigation of the Second Miyakojima Typhoon (6618, Cora) the following results are obtained:-

(1) The maximum wind speed observed in Miyakojima was 60.8 m/s and the rates of completely destroyed and damaged houses were 17.5 % and 48.7 % respectively in Miyakojima.

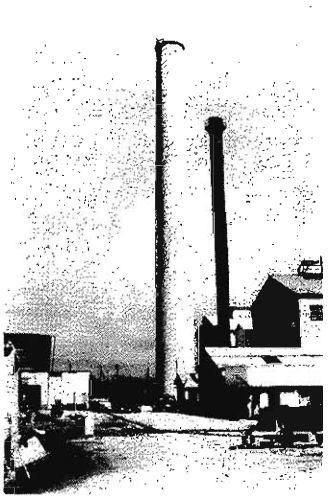


Photo. 10 Stacks in a sugar factory : no damage.

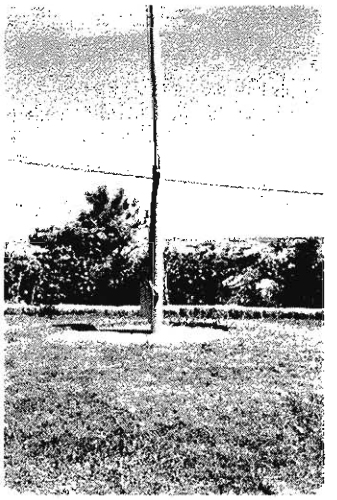


Photo. 11 Damage to a flag mast : displacement of the top about 30cm leeward.

(2) In Ishigakijima the rates of completely destroyed and damaged houses were as small as 0.9 % and 2.6 % respectively, which seems to be mainly due to the relatively long distance from the center of the typhoon and also to the wind-shelter effect of the topography.

(3) In the city zone of Hirara City the damage rate was smaller than in the rural districts, and the windward area in the city was more seriously damaged than the leeward.

(4) The damage to wooden buildings was as follows:-

The damage to walls appeared to occur at openings, which was closely related to the removal of roof tiles in the case of roofings without bed boards. The damage to tiled roofs appeared to occur on eaves, ridges, verges or corners, and was extensive in the case of roofings without bed boards.

(5) Reinforced concrete buildings or tower structures only suffered local damage.

Acknowledgements

The authors desire to convey their thanks to the many residents of the region affected by the disturbance, for their assistance in supplying information at a time of great stress. Also to Mr. Tokumatsu Maeshiro, Mayor of Hirara City, who afforded facilities for the investigation, and to the Government of the Ryukyus and local administration offices in Miyakojima and Ishigakijima for their cooperation in supplying information.

In addition, thanks are due to the following organizations, who supplied photographs of the devastated region; the U. S. Civil Administration of the Ryukyus, the Miyako Bureau of Local Administration, Hirara City Hall, Ishigaki City Hall, Hirara Fire Department, The Ryukyu Shimpo and The Okinawa Times.

References

1) Y. Mitsuta and S. Yoshizumi, Characteristics of the Second Miyakojima Typhoon, Bulletin of the Disaster Prevention Research Institute, Kyoto Univ., vol. 18, Part 1, 1968.

2) Y. Mitsuta, K. Miyata and S. Yoshizumi, Severe Wind Storm Caused by the Second Miyakojima Typhoon, Annuals, Disaster Prevention Research Institute, Kyoto Univ., No. 11A, 1968. (in Japanese)

3) Building Code for Use in Okinawa, Wind Load.